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DEVICE FOR DETECTING A MECHANICAL ACTUATION OF AN INPUT
ELEMENT BY USING DIGITAL TECHNOLOGY, AND METHOD FOR
PROCESSING AND CONVERTING THE DIGITAL INPUT SIGNAL INTO
COMMANDS FOR CONTROLLING A LOAD

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The following invention describes an apparatus for the
sensing of input pulses caused by the mechanical activation
of an input element, that are activated during the operation
10   of electronic devices by an operating person as well as a
procedure to process the values of the input pulses related
to the measurable position of the activation.

The following techniques are known to in order to determine
15   the position of a switch element of electronic devices in the
sense of a mechanical movement during activation:

-       so-called analogue joysticks of computer games contain
        two potentiometers that are mechanically coupled to the
20   tilt of the joystick. Their electrical resistance
        corresponds to the x- and y-values of the tilt.

- Discs with holes can deliver digital signals when combined with light barriers (opto couplers) to report the position of a switch element. When the travel distance is sufficient, a high resolution can be achieved.

- Force sensors such as strain gauges, force sensing resistors (FSR) or hall sensors deliver analog signals. Their values are related to the force applied to the sensor. This is even possible with a small travel distance.

- Seesaw keys, often implemented as 2-way or 4-way cursor key pad, measure one level in any of two or four directions, and sometimes also the activation of the middle position. With significant mechanical cost, special combination switches can also determine a few more steps.

The solution with potentiometers is mechanically expensive, results in a certain weight and it is subject to vibration and shock. Thus, potentiometers are less suitable for mobile devices. Discs with holes and opto couplers are smaller, lighter and deliver a digital signal. They are also subject to mechanical vibration and also against dirt.

In contrast, force sensors can be built very small and mechanically robust. However, they require a complex electronic controller with an interpretation of sensed analog

signals. This high cost prevents the mass usage of force sensors with electronic devices.

Seesaw keys, on the other hand, are commonplace because they are small, light, robust and low-cost. However, they only offer 2 up to 5 switch positions so they are not suitable for the operation of graphical user interfaces.

A variable activatable input apparatus for cursor control on a PC display is known from US-5,815,139. This apparatus makes use of an input element that can be freely moved within one plane, and that allows to register the positions of the tilted input element changed by mechanical force applied to flat sensor. The tilt and force applied to the input element can be determined by measuring several variable resistances. During this process, analog measured values are delivered that can show inaccuracies due to temperature dependance. The processing of the measured values requires digitizing them, making a controller necessary.

Several analog systems are known to transmit the movements forced to an input element for mechanical devices. These are complicated to manufacture and thus expensive. The mechanical devices can also be controlled by electrical transmission systems, however there are no complementary low-cost apparatus to sense the mechanical activation of an input element, so that it could detect any position of an input element during a mechanical activation during any movement phase.

The targets of the invention are to create an apparatus to sense input pulses that are caused by a switch element that determines the activation position of a mechanical activation of an input element, as well as a small and robust
5   construction, a low-cost design, easy-to-learn operation and a precise processing of the resulting input pulses with electronic devices.

The invention's task is to develop an apparatus for sensing
10   and processing input pulses that are caused by XXX 4/5.

The task is solved by the features described in the independent patent claims.

15   According to the invention, a user interface element, e.g. a key or a joystick is tilted against an elastic force, whereas an electrical conductive area at the underside of the user interface element touches a contact matrix at varying positions and thus closes electrical contacts. The closed
20   contacts are related to the tilt of the user interface element, where the closed contacts delive measurement values which are interpreted by by an electronic controller, and where the procedure according to the invention determines the tilt, the direction of activation and the pressure force.
25
The invention will be demonstrated by means of an example.
The figures are as follows:

Fig. 1:   a general structure of an apparatus according to
30   the invention

Fig. 2:   Possible operations of an input element of an
           apparatus according to the invention with an
           activation in vertical direction at various
           positions

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Fig. 3:   Possible operations of an input element of an
           apparatus according to the invention with an
           activation in vertical and then tilted directions

Fig. 4:   Possible operations of an input element of an
10   apparatus according to the invention with an
           activation in tilted direction

Fig. 5:   an implementation of an input element according to
           the invention, form factor „key", position after
15   vertical activation in the center of the input
           element with small force

Fig. 6:   closed contacts according to Fig. 5

20 Fig. 7:   an implementation of an input element according to
           the invention, form factor „key", position after
           vertical activation in the center of the input
           element with high force

25 Fig. 8:   closed contacts according to Fig. 7

Fig. 9:   an implementation of an input element according to
           the invention, form factor „key", position after a
           tilted activation at one edge of the input element

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Fig. 10:   closed contacts according to Fig. 9

Fig. 11: closed contacts according to Fig. 9 with an
          alternating force

Fig. 12: an implementation of an input element according to
          the invention, form factor „key", position after a
          one-sided tilted activation at the outmost edge of
          the input element

Fig. 13: closed contacts according to Fig. 12

Fig. 14: an example for the design of the conductive paths,
          to determine the degree of tilt within one axis
          (one-dimensional sensor)

Fig. 15: another example for the design of the conductive
          paths, to determine the degree of tilt within one
          axis (one-dimensional sensor)

Fig. 16: a two-dimensional sensor with a disc-type input
          element, viewed from the top

Fig. 17: a two-dimensional sensor with a disc-type input
          element, viewed from the bottom

Fig. 18: a two-dimensional design of conductive paths

Fig. 19: another two-dimensional design of conductive paths

Fig. 20: another two-dimensional design of conductive paths

Fig. 21: an example for the closed contacts of a two-
          dimensional sensor

The apparatus according to the invention for sensing and processing of input pulses evoked by activation of input elements, and for the conversion of a digital input signal into commands for operating electronic devices consists of at least one input element 11 that is formed like a key and can be operated by a finger movement. Opposite its activation surface 10, on its underside 19, this input element features a calotte 12 consisting of a single material. The calotte 12 is formed like a ball and is coated with an electrical conductive contact coating 18 on a convex surface oriented towards the contact matrix 15, where the input element 11 is mounted manouevrable against an elastic force 13 within a casing not shown here. Underneath the input element 11 there is a base plate 14 that features a contact matrix 15 which is connected via an interface with a scanning unit 16 for a real-time analysis of input pulses, that is subsequently connected to a pattern recognition unit 17.

The input element 11 is operable with a finger movement on the activation surface 10, alternatively in a vertical direction in the key center 22 like a pushbutton, or on its left edge 21 or its right edge 23. This allows the contact coating 18 of the calotte 12 to close various contacts of a linear arrangement, i.e. alternating sequence of the contacts 142, 143, 144, 145 and 151 within the contact matrix 15 depending on the position of the input element 11. The input element 11 can be activated not only as described in vertical direction; if the key center 22 is kept pressed in a vertical direction, the input element 11 can be forced into a rolling movement 24 either in the right or left direction. Depending on the degree of the rolling movement of the calotte 12, the

contact matrix 15 connects different contacts; additionally the applied force plays a role for the contact connections. If the calotte 12 is made of a deformable material, a varying pressure of the finger applied to the input element 11 leads

5   to a varying number of contacts closed simultaneously within the contact matrix 15 through the contact coating 18 of the calotte 12. Alternatively, the input element may be used with a joystick movement 25. The possibilities of contact connections depending on the described modes of operation of

10 the input element 11 are shown in Fig. 5 to 12; indicating a stronger force on the input element 11 with a bolder arrow symbol.

    The contact matrix 15 consists, as shown in Fig. 14 and 15,
15 of several electrical single contacts 142, 143, 144, 145 and 151 in a contact row, which are mounted on a base plate 14. The contacts are activated by the calotte 12 with its contact coating 18, which can optionally consist of a deformable material that ensures a pressure-dependent number of several

20 contact closings. The calotte consisting of a deformable material may alternatively not be equipped with a contact coating 18 but consist of a electrically conductive material; this is another aspect of the invention. The activation surface of the input element 11 can adopt any geometrical

25 shape of a flat surface. In practice, two specific forms have evolved, a rectangular and a circular shape. The basic shape of the calotte 12 depends on the selected shape of the activation surface 10. Other than the line-sequence arrangement of contacts in the contact matrix 15, another

30 aspect of the invention allows to adapt the form of the contact matrix 15 to the activation surface 10. This allows to operate the input elelement 11 like an analog joystick,

where the user's movements of the input element 11 are detected.

The switch contacts of the contact matrix 15 are scanned by a
5 scanning unit 16, as known from conventional keyboards. With the sensor designed according to the invention, however, the number of switch contacts is much higher. Depending on the tilt of the input element 11, different contacts on the contact matrix 15 are closed, as the convex underside 19 of
10 the calotte 12 of the input element 11 is rolled on the contact matrix 15.

The plurality of switch contacts of the sensor lead to ambigous switch conditions, that cannot be interpreted by
15 conventional circuitry. An innovative pattern recognition scheme as implemented by the procedure according to the invention interprets the switch conditions and assigns a tilt position and the orientation of the input element 11 to them and optionally the applied force.
20

In its simplest form, the sensor consists of only two switches, which can be associated with four switch conditions (off, left, center, right), the center condition being reached when both contacts are closed at the same time. If
25 more switches are available, a much higher resolution can be achieved; and with redundant contacts the reliability can also be improved.

Depending on the implementation of the sensor, the movement
30 resp. the tilt of the input element 11 can be determined either on one axis or on two axis. This requires a one-dimensional resp. two-dimensional contact array. Additionally

it is possible to conclude the applied force from the deformation of a soft calotte 12 and the resulting number of closed contacts. The input element 11 with a convex calotte 12 at its underside 19 is held in a center position against 5 the base plate 14 by an elastic force 13. If the input element 11 is pressed into the direction of the base plate 14 with one or more fingers, then the calotte 12 ensures electrical connections at certain positions of the contact matrix 15. In this context, the input element 11 is 10 manouevrable downwards and tiltable.

The invention can be used in connection with a graphical user interface with various usages. Depending on the situation, different applications can be offered on the display. It is 15 possible to implement parameter settings, menu navigation, key input and mouse pointer control with identical hardware.

While ordinary keys only differentiate between a passive state and a key activation, the invention allows to register 20 the details of operation through connections of the contact matrix 15 in so much detail, that the tilt of the input element 11 allows to conclude the position of one or more finger on the input element 11.

25 Fig. 2 shows which typical user interface actions cause the tilt of a flat input element 11 that is similar to keys. The simplest case is that the input element 11 is activated at its left edge 21, at its center 22 or at the right edge 23, with an ordinary brief press on the input element 11. The 30 apparatus according to the invention does not just receive an ordinary signal for the activated key, but also an information on which position the key has been activated.

This allows the invention for example to distinguish between alternative key assignments within an single keypress.

Fig. 3 illustrates the case when a key is pressed in its key center 22 and held in that position. Even in the held-down state it is still possible to manipulate the input element 11 with the finger, so that the tilt of this key changes into the direction 24. From this user interface action, the apparatus according to the invention does not just receive a singal for a continously held key, but also an up-to-date information about the specific tilt of the input element 11. This allows to activate and control a cursor movement with the invention.

Fig. 4 shows an application where a permanently resting input element 11 can be moved like a joystick etc.. The element bounces back into the center position when released.

Fig. 5, 7, 9 and 12 show cross-sections of four different states of an input element 11 according to the invention. Fig. 6, 8, 10, 11, and 13 show the corresponding contact matrix as a pattern resulting from each activation. In these figures, open contacts are indicated with a white rectangle and closed contacts are indicated with a black rectangle.

Fig. 5 shows an input element 11 that has been normally activated in the center. The contact medium on the underside of the input element touches the conducting paths of the contact matrix 15 in the center accordingly, as indicated on Fig. 6 with two black rectangles.

On Fig. 7, the same input element 11 has been pressed slightly harder. Now the soft underside of the input element is deformed, i.e. the calotte 12 (e.g. a pill made from electrically conductive rubber), resulting in contact between many points of the contact matrix 15, and a signal is generated with four little boxes. The difference between Fig. 5 and Fig. 7 means that the construction according to the invention is capable of measuring the force applied to the input element 11; although this is only done indirectly through the deformation of the contact medium of the calotte 12.

Fig. 9 displays the input element 11 activated at the left edge 21. This could result in contacts of the contact matrix 15 as shown in Fig. 10 and a corresponding signal. However, considering the huge number of contacts in the contact matrix 15 it is possible that single contacts fail in exceptional cases as illustrated on Fig. 11. The procedure to sense and process input pulses evoked by mechanical activation of input elements according to the invention leads to useful results even in such a case. This is because the electronic controller of the pattern recognition unit 17 determines the center of the closed contacts in terms of the mathematical average of the position. This means that even in this case a reflection of the tilt of the input element 11 comes as a result.

Fig. 12 shows the input element 11 activated on the extreme right edge 23, accordingly the contacts 63 are closed and the signals appear at the right side of the contact matrix as indicated on Fig. 13.

The procedure according to the invention allows to either determine the tilt of an input element along a single axis as shown on Fig. 5 to Fig. 13, or alternatively the tilt of the input element 11 in arbitrary directions can be registered.

5 This depends only on the convex underside of the input element 11 (longish or circular) and the contact matrix 15 (strip-like or more like a square).

In order to measure on a single axis, a contact matrix as
10 shown on Fig. 14 or Fig. 15 is sufficient. The underside of the input element 11 must lie down on these contacts when mechanical force in the range between 20 and 500 grams is applied. Depending on the tilt of the input element 11, different contacts of the contact matrix 15 are closed. On
15 Fig. 14 and 15 the potential resting area of the calotte 12 that is moved with the input element 11 appears as a screened rectangle 141.

On Fig. 14, six conducting paths with contacts lead to the
20 top and another six lead to the bottom, the calotte 12 is capable of connecting them. Such a contact matrix could therefore differentiate approximately six activation angles; to be precise, even more as intermediate values can be recognized through the combination of multiple contacts. The
25 contact matrix 15 shown in Fig. 15 even allows to distinguish between eight activation angles with a lower count of conducting paths, as several conducting paths have been combined.

30 In its simplest case, a contact matrix 15 for a procedure according to the invention could get along with three conductive paths: left side, right side and the electrical

antithesis. This would result in only three activation angles (only left side or both or only right side). This would be a very inaccurate measurement, that could still be useful depending on the application.

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Fig 16. shows an input element 11 shaped like a disc, that can, originating from a home position in the center 161, be moved into any direction by pressing the edge 162. Fig. 16 shows an example of an upper side of such an input element 10 11, while Fig. 17 shows the underside with a large circular calotte 12 in its center.

This shape of a calotte 12 could encounter grid-like conductive paths equipped with contacts, for example, as 15 shown on Fig. 18. With a large number of contact points, the conductive paths must be placed in two electrically separate layers. The right side of Fig. 18 shows an enlarged detail of the conductive paths, the vertical conductive path placed underneath and electrically separate from from the horizontal 20 conductive path. Fig. 19 and Fig. 20 show further examples of such conductive path layouts, where Fig. 20 requires only a singel layer of conductive paths.

The electronic scanning unit 16 shown on Fig. 1 determines 25 which connections are closed and derives from it a bit pattern that includes all possible contacts. Scanning the conductive paths is similar to the scanning of an ordinary PC keyboard. The different contact combinations are subsequently supplied with signals and on the other side the level signals 30 whether there is an electrical connection in the specific row or column.

Fig. 21 and Fig. 22 show examples of such bit patterns derived by scanning. Fig. 21 shows the result of a medium force in the upper left area. The single light contact point within all the black spots indicates a possible defect of a

5   single contact point: Considering the large number of contact points and the possible rapid movement of the control element, a perfect contact is impossible and not even necessary. The pattern recognition unit 17 shown in Fig. 1 calculates the average of the registered conductive paths

10 automatically. With Fig. 22, the lower count of contacts clearly indicates that the applied force on the control element is lower than in the situation of Fig. 21.

The procedure to sense and process input pulses according to

15 the invention can be adapted to different shapes of input elements, as shown on Fig. 23 to Fig. 27. The input element 11 is mounted flexible in a way that it can be pressed downwards and to the sides, but returns to its original position whenever it is released.

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The input element 11 can be designed in a shape that resembles well-known keys from pocket calculators, mobile phones etc. (Fig. 23 and Fig. 24). The calotte 12 serving as a contact medium (shown black in these figures) however has a

25 special curvature, that closes different single or multiple contacts of the conductive paths depending on the tilt. In its simplest form, only two contacts can be closed that are established with three conductive paths. This allows to distinguish three separate activation angles apart from the

30 passive state. The calotte 12 is accordingly flat in its center and bevelled to the edge, to allow three positions with a specific activation angle for each.

This most basic implementation of the invention differs from
known seesaw keys in that way, that with the input elements
according to the invention either one, the other or both
5   contacts   may be closed (two signals, three conditions),
whereas with ordinary seesaw keys only a single contact may
be closed at a time (two signals, two conditions).

Besides, the input elements according to the invention
10   exhibit none or only a single tactile threshold. Even when
due to low count of conductive paths no individual tactile
thresholds can be felt with the elastic force 13 of Fig. 1,
it is still possible that certain edges 234; 235 of the
calotte 12 can be felt during a movement of the input element
15   11 in held-down state according to Fig. 3.

With known seesaw keys however, every position requires a
separate tactile threshold, because otherwise no unambigeous
activation would be possible. This means that the mechanical
20   construction of known seesaw keys is complex, as the
transition between the combined keys means an unstable
connection. With the invention, however, the transitions and
multiple contacts pose no problem; in the contrary they are
utilized to determine the tilt of the input element 11.
25
With an input element 11 with a larger number of contacts
(Fig. 24) the calotte 24 is rounded like a cutout from a
globe. The diameter of this fictional globe should
approximate the size of a human hand, as the input elements
30   11 are tilted with the hand.

A group of input elements 11 in the shape of keys according to Fig. 23 and Fig. 24 can be produced like keyboards of common electronic devices from a silicon rubber mat, that integrates the upper side of the input element 11, the elastic force at its edges and the fixing in a single flexible component.

This allows a cost-effective production and allows the combination with ordinary keys. According to Fig. 23 and Fig. 24, the contact medium can be implemented as a carbon pill resp. made from electrically conductive rubber; these materials are widely known and used for keyboards.

Alternatively, a polyester dome foil can be mounted between the input element and the conductive paths, which fulfills the functions of the elastic force and with a conductive coating on its underside such as carbon, metal etc. fulfills the function of the contact medium (Fig. 25). Such input elements shaped like key domes can alternatively be built completely from metal and are usable for a construction according to the invention, as long as the metal dome is soft enough to ensure contacts according to the tilt.

A joystick on the basis of the same materials as Fig. 23 and Fig. 24 is shown Fig. 26. Such a design is cheap to produce and easy to combine with keyboards.

At last it is possible to mount an input element detachable on a touch screen as shown on Fig. 27. Touchscreens typically register a mechanical activation on a single spot of a display. The input element according to the invention creates exactly such a pressure concentrated on a single spot, where

the touch position depends on the tilt. The grey shown base plate 14 covers the touch screen and protects it from mechanical pressure; at well-defined notches underneath the input elements any input element can however reach the
5   touchscreen and activate it at different coordinates depending on the tilt.

As a permanent construction it would be unreasonable to create such a combination, as a touch screen costs much more
10   than a contact medium in the form of a calotte together with conductive paths. However, as an alternate input device this solution might be useful, e.g. as a keyboard that could be mounted on a palm computer with tilting keys offering multiple key assignments, or as an optional mountable
15   joystick for game control.

Palm computer and smart phones feature a casing 281 (Fig. 28) containing a large touch-sensitive display 271 as an input device (Fig. 28). Such a touchscreen is suitable for
20   operating a graphical user interface with a pen or with a finger directly on the display 271. At the same time, a touchscreen is less suitable for games (a joystick would be preferable for these) and also less suitable for data entry (keys would be preferable for input).
25

The invention allows to equip such a touchscreen device with additional input elements 11 within a very small space. To this end, the base plate 14 of a unit according to the invention (Fig. 29) with input elements 11 (Fig. 29) is
30   mounted from the top or the side of the casing 281 (Fig. 29), in a turn-over or clip manner, so that a part (max. 50%) of the touchscreen, i.e. the display 271 (Fig. 29) is covered.

The rest of the display is still available for software displays.

The touchscreen surface 271 can be touched mechanically underneath the base plate 14 by single input elements 11, if these are activated (Fig. 30). The base plate 14 could for example be clipped to the sides of the casing 281 (Fig. 30).

The electrical contacts that are closed through the activation of the input elements 11 through the contact medium, the calotte 12, are subsequently scanned by a electronic component, the scanning unit 16. This scanning is a well-known procedure, that is in use with almost every keyboard of an electronic device, so there is no need to describe it in detail here. Existing devices make use e.g. of a contact matrix of 8 x 8 conductive paths to scan a keyboard with up to 64 keys; the invention uses a similar contact matrix for of a single input element 11. The contacts are scanned just like keyboards with changing pulses in a rate between 5 and 50 scans per second.

The result of the scanning creates a bit pattern that is transmitted from the scanning unit 16 to a micro controller with software, the pattern recognition unit 17 for evaluation (Fig. 1). After every scan cycle, a yes/no information is transmitted for every conductive path which indicates whether the specific contact is closed (i.e. touched by the contact medium) or open. This bit pattern allows the software to calculate the position (resp. the tilt) as well as the applied pressure of the activation, if required.

The number of conductive paths can be varied depending on the application. More paths allow a higher precision of the tilt measurement, but require higher cost. In practice, between three and twenty conductive paths will be reasonable for a one-axis measurement (as seen on Fig. 14 and Fig. 15) and with a measurement into all directions, between six and a few hundred contact points.

The steps are listed in detail on Fig. 31. After the start, all input elements are checked for activation at step 312. It is possible to evaluate a single element only or alternatively it is possible to combine multiple input elements and evaluate them with one electronic circuit. Step 312 ensures, that the following calculation are based on the activated element and it is repeated (313), until an activation is detected.

After this, the conductive paths of the activated element are analysed 314. The bit pattern of the contacts allows to conclude the activation angle, i.e. the tilt of the element 315 by calculating the average of the positions. For instance, if there are ten conductive paths in one axis with an input element 11 and the paths 2, 3 and 5 are connected, then step 315 will make the following calculation: (2+3+5)/3 = rounded 3.33. Normally, all conductive paths are placed in a regular interval, and the calotte 12 will react to a changed angle with a proportional change of the contact position. In such a case, the average of the contact positions directly resembles the tilt. For special applications, the conductive paths could also be placed in irregular intervals or the contact medium calotte 12 can be especially flat or steep. In these cases, the controller must

determine the tilt with a table or specific formula that reflects the mechanical characteristics.

Step 316 (Fig. 31) determines the applied force, if this is relevant for the application. In order to achieve this, the number of closed contacts is simply counted. A stronger pressure leads to a stronger deformation of the contact medium (calotte 12) and thus to a larger number of contacts.

This kind of force measurement is inaccurate and will in most cases only allow to distinguish between three and eight levels of pressure. The exact conditions depend on the hardness and the form of the contact medium (calotte). If a higher precision of force measurement is required, this can be achieved with a higher number of conductive paths, a softer contact medium (calotte) and a more accurate formula to reflect the mechanical characteristics of the contact material (calotte).

At step 317, the result of the calculation are delivered to the operating system (OS), where they may be used to control a cursor, for a game control or for data input.If the input element is activated continously, the steps 313 to 317 are repeatedly passed, i.e. a possibly changed activation position or force is permanently evaluated.

The sensor according to the invention constitutes a significantly more compact sensor than potentiometers or discs with holes can offer in order to determine the tilt of input elements. Therefore, it can easily be integrated into mobile electronic devices just like known force sensors and seesaw keys. The different properties of known technologies

in comparison with the invention are shown in the table of Fig. 32.

Force sensors make use of FSR (Force sensing resistors), strain gauges or hall sensors as a basis for measurement. By contrast, the known keys simply close an electric contact. The invention integrates a plurality of electrical switches into a single mechanical input element.

Force sensors are used for example to operate of the mouse pointer of notebook computers, by mounting a small joystick between the keys (TrackPoint). A sensor underneath the TrackPoint measures the lateral force that a person applies to it. A mechanical tactile threshold, similar to a key function, that would precede an activation is not provided. However, there are versions of TrackPoint controls that allow an activation depending on a higher pressure like a mouse key function. Normal keys only react to an activation from the top, i.e. force applied downwards. With the invention however, it is possible to register the tilt of an input element with a scalable resolution and at the same time the function of several keys in a single input element is integrated. But this key function can be dropped depending on the application, so that the invention can be used solely for cursor control. A tactile threshold as with normal keys is possible with the invention, but could be dropped as well.

Typical force sensors allow to control a with a variable speed. This is also possible with the invention, while ordinary keys do not offer such a function. Force sensors have this capability because they can measure several levels of pressure, the resolution resulting from the sensor

hardware. The established force sensors, especially strain gauges, offer a high resolution of over one hundred steps. This makes them adequate for controlling the mouse pointer of a notebook computer. With smaller electronic devices, this

5   precision is actually a disadvantage because it is not required and increases cost.

Keys do not allow a variable activation and therefore they are not capable of analog control. The invention, however, is

10   scalable in the way that depending on the requirements a higher or lower number of conductive paths can be applied. At the same time, the input element itself can be kept unchanged.

15   With force sensors, there is a definite relationship between the analog input signal and the result of the required controller circuitry for analog-digital conversion. With switches, there are only two alternatives, open or closed. The invention, however, does evaluate digital signals of the

20   conductive paths, but it requires a pattern recognition procedure in order to calculate a position and if necessary the force from a number of parallel activated switches.

If the tilt of the input element is evaluated on two axis,

25   then the analog signals of multiple force sensors can be interpolated to determine the tilt direction. For example, if a sensor in a north direction is activated as strong as a sensor in west direction, then it can be concluded that the control element is tilted towards north-west. This is a well-

30   known technology. The precision of analog force sensors allows to differentiate more than one hundred segments of a circle.

Ordinary switches can differentiate as many directions as there are switches, i.e. normally two or four. However, the invention allows to differentiate between many more circle segments, depending on the number of conductive paths, but less than with force sensors. For compact electronic devices, this is fully acceptable.

Force sensors and the corresponding analog evaluation electronic circuits are more or less temperature-sensitive; aging of components, production tolerances or lack of calibration can also lead to inaccuracies. Switches and the invention are not affected by this problem at all.

The solution according to the invention is much more reasonably priced, it is more robust and more compact than traditional potentiometers and code switches. The invention goes far beyond traditional key functions and is thus practical for the operation of powerful software user interfaces with many functions. The resolution of the measurement is lower than with high-grade force sensors. On the other side, the fully digital evaluation and the almost perfect stability still guarantee a precision that is comparable to force sensors.

The digital interface and the form factor that can be manufactured automatically as a component of keyboards allows to produce the invention a level of scale cheaper than force sensors. The effort and the resulting expenses are only slightly higher than traditional keyboards.

The scalable precision and the various constructions allow to adapt the invention to almost any requirements; notably it offers both functions for cursor control as well as functions for data entry in keyboard style.

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The measurement of the tilt of input elements for mobile electronic devices requires sensors to control cursors and to operate the powerful software of current electronic devices, where the demands for the cursor positioning are lower for a

10 mobile device with a smaller screen than with a huge display.

Such sensors must be small, light, robust and easily and automatically producable. It is an advantage if the sensors consists of very few components and can be integrated into

15 keyboards. The solution described by this invention fulfils these requirements.

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Translation of Figures

Fig. 24 – concave
Fig. 25 – dome

Fig. 32

	Force Sensor	keys	Invention
technology	Sensor	Switch	switchmatrix
Measurement of	Force	Perpendicular release	skew
Key function	No	yes	alternatively
Mechanical pressure point	No	Yes	alternatively
Multi-level	Yes	No	Yes
Number gradation	Firmly, many	2	variable
Pattern recognition	no	No	yes
evaluation	analog	Digital	digital
Circular cut-off	Ca. 20-200	2-4	2 ca. - 50
Rate constant	No	Yes	yes